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Use of the Moon as a reference for satellite-based climate change measurements

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ABSTRACT

The United States Geologic Survey (USGS) has developed a lunar irradiance model for comparison with on-orbit satellite instruments. The comparisons are given as the percent difference of the satellite measurements from the model-generated lunar irradiances. For users of the USGS lunar model, details of the inner operation of the model are unknown. That operation is not examined here. Rather, we examine the outputs of the model. We treat the model-generated lunar irradiances as independent data sets, with each covering only a limited range of phase angles in the comparison with an individual satellite instrument. We correct the model irradiances to standard Sun-Moon and Moon-instrument distances and to fixed values for the phase and libration angles. These same corrections can be applied to the measurements by the comparison satellite instrument. For the model outputs examined here, the time trends in the corrected irradiances differ from zero change by less that 0.0014 % per thousand days, and the residual scatter in the results is 0.013 % (1σ). There are no apparent oscillations in the time series. At this level, the lunar model should provide an adequate reference for instruments that measure long-term climate change. The model outputs here correspond to the bands from the Sea-viewing Wide Field-of-View Sensor (SeaWiFS) instrument and to the phase angle range for the SeaWiFS lunar measurements, which is from 5° to 10°, both before and after full phase. Similar results have been obtained for model outputs corresponding to lunar measurements from the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments onboard the Terra and Aqua spacecraft. This technique is applicable to other instruments that measure at wavelengths from 400 nm to 2500 nm since, in addition to the relative spectral responses of the instrument's bands, the only requirements for the model are the time and location of the instrument's lunar measurements.

Keywords: Moon; on-orbit calibration; spacecraft

1. INTRODUCTION

Over the last decade, the United States Geologic Survey (USGS) in Flagstaff Arizona have produced a photometric model of the Moon for use as a calibration standard for satellite instruments.[1-10] From ground-based observations at Flagstaff, they have developed a model of the Moon's spectral reflectance. To accomplish this, they have accounted for the effects of solar and lunar distance, and of lunar phase and libration in their observations. Using this model of reflectance, phase, and libration, the irradiance for a given spacecraft's lunar observation can be calculated. Kieffer[11] has shown that the lunar surface is photometrically stable over a period of 10^6 years. However, the actual comparisons of the model with the instruments include the time-dependent, cyclical changes in the lunar irradiance as viewed by the instruments.

Here, we investigate the lunar model by reverse engineering its outputs, that is, we develop an analysis to remove the phase and libration effects from those outputs for a specific instrument comparison. In so doing, we derive an estimate of the quality of the USGS model as an unchanging lunar reference for satellite instruments making long-term measurements of the Earth. The satellite instrument for the demonstration of these results is SeaWiFS, which makes lunar measurements near 7° before full phase and near 7° after. The results of the demonstration come from a comparison of 69 SeaWiFS measurements with the lunar model.

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